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Insects Attacking *Cordia macrostachya* (Jacq.) Roem. & Schult. in the West Indies

1. *Physonota alutacea* Boh. (Coleoptera, Cassididae)

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Introduction

About the year 1890 the plant *Cordia macrostachya* (Jacq.) Roem. and Schult. was accidentally introduced into Mauritius with a consignment of sugar-canes from the West Indies. Later *Cordia* was spread artificially around the island in an effort to encourage the increase of *Tiphia parallela* Smith. This parasite was introduced into Mauritius as a possible control agent for the sugar-cane root-grub, *Clemora smithii* (Arrow), and it was found that adult Scoliids fed at the inflorescences of *Cordia*. (Box 1928). Since that time *Cordia* has spread considerably and has become a serious pest in Mauritius (for details see Wiehe 1946).

In 1942 suggestions were made that the biological control of this weed should be attempted, and in 1944 preliminary work was started in Trinidad at the Imperial College of Tropical Agriculture. (Kirby and Adamson 1944). In 1945 further investigations were carried out by Donald (1945). Also in 1945 Mr. P. O. Wiehe came from Mauritius to investigate the status of *Cordia* in the West Indies (Wiehe 1946), and in 1946 I started work on this problem.

It is intended to publish the results obtained in a series of papers, each dealing with the biology of one or more species found attacking *Cordia* in the West Indies. The present paper concerns the biology of a beetle, *Physonota alutacea* Boh., which causes considerable defoliation of *Cordia* in some restricted areas, and may possibly in Mauritius, if freed from the natural checks to its increase that occur in the West Indies, cause substantial damage to the weed.

Systematic Position and Adult Characters

Physonota is an American genus of the family Cassididae, which is closely related to the Hispidae. It was described by Chevrolat in 1837, (Catal. Coleopt. Coll. Dejean, 3rd. ed. p. 398) and subsequently by Boheman in his Monograph on the Cassididae (Pt. ii p. 190) in 1854. In the Biologia-Centrali-Americana (Coleoptera VI. pt. 2, pp. 166, 1894) the genus *Physonota* is restricted to those species with simple, not appendiculate, claws, and the species *P. cyrtodes* is considered as a variety of *P. alutacea*.

The adults of *P. alutacea* are yellowish-white on emergence, but as the chitin hardens the colour changes. A few hours after emergence the beetles are dull grey with blackish spots, and after a further week or so they have become pale metallic turquoise with scattered dark spots. This turquoise colour becomes duller with age. The marginal flanges of the elytra etc. are paler, with a fawn tinge. The beetles are broadly oval in shape, about 12 mms. (10-15 mms.) in length and 9 mms. (7-10 mms.) in greatest breadth, halfway down the elytra. The body is strongly convex. The extent of the black markings on the terminal sternite appears sometimes to be different in the sexes, but this is not a reliable difference, and the sexes can only be safely separated by dissection, observation of pairs mating, or by an estimation of daily food consumption (see next page).

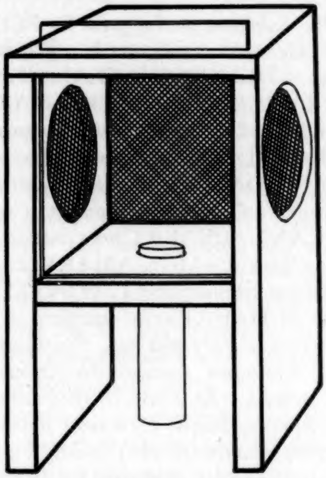
Distribution and Food Plants

In the Biologia Centrali-Americana *Physonota* is recorded from many localities in Mexico, Guatemala, Nicaragua, Costa Rica, Panama, Colombia and Venezuela, but no mention is made of food plants. In Trinidad the beetle was recorded in 1944 from derelict areas secondarily invaded by *Cordia* on the Caroni Estate, where it occurs commonly over a small area. It has now been found in surrounding areas similar ecologically to the Caroni locality. Two specimens in the collection at the Imperial College of Tropical Agriculture are labelled "St. Augustine", some miles from Caroni, and Donald (1945) gives further records from Maraval, Maracas Valley and Biche.

The restricted distribution of the beetle in Trinidad is in striking contrast to the ubiquity of its host plant, *Cordia*. Hence some experiments were made to determine the cause of this. Large colonies of the beetle consisting of 50 or 100 adults and several hundred larvae of various stages were liberated on *Cordia* bushes at a number of different points away from the Caroni area. In none of these did *Physonota* become established even though the adults lived for a considerable time and laid eggs normally. Investigation showed that ants appeared to be the main factor responsible for non-establishment (see "Predators" below). Eggs laid in the new environment hatched normally but within a very short time ants had removed all the young larvae hatching from each egg-mass, wasps removed some of the older larvae liberated, and numbers of pupae were bitten into and their body contents removed by ants. In spite of repeated attempts no adults could be bred in the field unless precautions were taken to protect the immature stages from ants and other predators. Hence it appears that in Trinidad *Physonota* will only be found in areas, ecologically similar to the Caroni area, unsuitable for certain species of ants.

Unfortunately no records are available as to the natural food plants of *Physonota* excepting those obtained in the present series of investigations. However Kirby and Adamson (1944) and Donald (1945) made a number of feeding tests with different plants, and these have been extended in the present work. Kirby and Adamson tested 34 plants with *Physonota* adults and also 1st and 3rd stage larvae. Adults ate small pieces of leaves of both *Cordia sebestena* L. and *C. colococca* L. but died without oviposition. First instar larvae lived for a maximum period of 3 days nibbling leaves of *Cordia sebestena, Mysotis scorpioidea* L. (=*palustris* Lam.), and *Brassica oleracea* L. Third instar larvae lived for a maximum period of 5 days, small holes were eaten in leaves of *Cordia sebestena* and *C. colococca*, and leaves of *Phaseolus vulgaris* L., *Lactuca sativa* L. and *Capsicum* sp. were nibbled. Donald used 37 plants in his tests, and adults nibbled slightly at leaves of *Nicotiana tabacum* L. and *Phaseolus lunatus* L. The larvae attacked only *Cordia macrostachya.*

In the present tests adult beetles that had been feeding normally on *Cordia macrostachya* were starved for at least two days, and ten such beetles were used in each test, placed in a small wood and cheesecloth cage (4½" x 4½" x 3") (Figure 1) containing a twig or leaves of the test plant. If no feeding whatever had taken place the plants were changed for another species the following day. After 5 such trials the beetles were placed with *Cordia macrostachya* again for 24 hours to ensure that they were still feeding normally (see below), starved for two days, and used again as before. Each plant species was also tested with *Physonota* larvae, when 10 cm. diameter petri dishes were used as containers, and fresh larvae were used for each test, each plant being tested with 20 1st stage larvae, 10 3rd stage and 10 5th stage larvae. Thus four stages of *Physonota* were tested with the 122 species of plants listed as follows.



1. Rearing cage for *Physonota.*

Plants offered to *Physonota alutacea* in feeding tests:

ANNONACEAE: *Anona muricata* L. CRUCIFERAE: *Raphanus sativus* L., *Brassica oleracea* L. (3 varieties), *B. caulorapa* Pasq., *B. chinensis* L., *B. rapa* L., *B. juncea* L. Cass. GUTTIFERAE: *Mammea americana* L. MALVACEAE: *Hibiscus cannabinus* L., *H. esculentus* L., *H. sabdariffa* L., *H. "rosa-sinensis"* L., *Gossypium barbadense* L., *Urena lobata* L. STERCULIACEAE: *Theobroma cacao* L. TILIACEAE: *Corchorus capsularis* L. (or *olitorius*?). RUTACEAE: *Citrus sinensis* Osbeck, *C. aurantium* L., *C. paradisi* Macfad., *C. aurantifolia* (Christm.) Swingle, *C. medica* L., *C. limonia* Osbeck, *C. reticulata* Blanco (=*nobilis*), *C. maxima*(Burm.)Merr. MELIACEAE: *Swietenia mahogani*(L.)Jacq. ANACARDIACEAE: *Mangifera indica* L., *Anacardium occidentale* L., *Spondias cytherea* Sonner. LEGUMINOSAE: *Pachyrhizus tuberosus* (Lam.) Spreng., *Mucuna* (*Stizolobium*) spp., *Phaseolus aureus* Roxb., *P. mungo* L., *Pueraria javanica* Benth., *Glycine max* (L.) Mur., *Crotalaria sericea* Rets,[1] *C. juncea* L., *Leucaena glauca* (L.) Benth., *Sesbania speciosa* Taub., *Dipteryx odorata* (Aubl.) Willd., *Gliricidia sepium* (Jacq.) Walp., *Erythrina glauca* Willd., *E. sp.*, *Vigna sinensis Sari* (=*unguiculata*) *Arachis hypogaea* L., *Derris elliptica Roxb.* (Benth.), *Stylosanthes guyanensis*, (Aubl.) Swartz, *Canavalia plagiosperma* Piper, *C. ensiformis* (L.) DC., *Dolichos lablab* L. MYRTACEAE: *Psidium guajava* L., *Melaleuca leucodendron* L. PASSIFLOREAE: *Passiflora quadrangularis* L. CARICACEAE: *Carica papaya* L. CUCURBITACEAE: *Cucumis sativus* L., (several varieties), *Luffa cylindrica* (L.) M. Roem., *Cucurbita pepo* L., *Momordica charantia* L. UMBELLIFERAE: *Anethum graveolens* L., (=*Peucedanum graveolens* Clarke), *Daucus carota* L., *Petroselinum hortense* Hoffm., *Apium graveolens* L. RUBIACEAE: *Coffea liberica* Bull., *Vangueria edulis* Vahl. COMPOSITAE: *Guizotia abyssinica* (L.f.) Cass., *Cichorium intybus* L., *Lactuca sativa* L., *Bidens pilosa* L., *Helianthus tuberosus* L., *Tragopogon porrifolius* L., *Scorzonera hispanica* L. SAPOTACEAE: *Chrysophyllum cainito* L., *Achras zapota* L. BORAGINACEAE: *Cordia macrostachya* (Jacq.) Roem & Schult., *C. colococca* L., *C. lockhartii* O. Ktze. CONVOLVULACEAE: *Ipomoea batatas* (L.) Poir. SOLANACEAE: *Capsicum annuum* L. (two varieties), *Nicotiana tabacum* L., *Lyco-*

[1]probably *C. spectabilis* Roth.

persicum esculentum Mill., *Solanum melongena* L. PEDALIACEAE: *Sesamum indicum* L. LABIATAE: *Ocimum basilicum* L., *Thymus vulgaris* L. BASELLACEAE: *Basella alba* L. CHENOPODIACEAE: *Tetragonia expansa* Murr., *Beta vulgaris* L. PIPERACEAE: *Piper* sp. LAURACEAE: *Persea americana* Mill. (=*P. gratissima*). EUPHORBIACEAE: *Ricinus communis* L., *Hevea brasiliensis* (HBK) Muell-Arg. URTICACEAE: *Boehmeria nivea* (L.) *Gundich*. MORACEAE: *Morus nigra* L. ORCHIDACEAE: *Vanilla planifolia* Andr. MUSACEAE: *Musa textilis* Nee, *M. balbisiana* Colla, *M. acuminata* Colla, MARANTACEAE: *Maranta arundinacea* L. CANNACEAE: *Canna edulis* Ker-Gawl. BROMELIACEAE: *Ananas comosus* (Stickm.) Merr. AMARYLLIDEAE: *Furcraea gigantea* Vent. LILIACEAE: *Allium ascolonicum* L. PONTEDERIACEAE: *Eichornia crassipes* (Mart.) Solms PALMAE: *Cocos nucifera* L. GRAMINEAE: *Coix lachryma-jobi* L., *Zea mays* L., *Polytoca* sp., *Pennisetum purpureum* Schum., *Tripsacum laxum* Nash, *Axonopus compressus* (Swartz) Beauv., *Euchlaena mexicana* Schrad., *Oryza sativa* L., *Saccharum officinarum* L., *Sorghum vulgare* Pers., *Brachiaria mutica* (Forsk.) Stapf, *Cynodon dactylon* (L.) Pers., *Melinis minutiflora* Beauv., *Vetiveria zizanoides* (L.) Nash, *Polytrias praemorsa* Hack., *Rottboelia exaltata* L.f., (=*Manisuris exaltatus* L.f.), *Trichachne insularis* (L.) Nees (=*Valota insularis chase*), *Tricholaena rosea* Nees (=*Rhynchelytrum repens* Willd.) Hubb., *Tricholaena repens* (Willd.) Hitchce.

In these experiments the beetles and larvae were not allowed to starve to death, and hence the tests are not individually as conclusive as the previous ones, but a far larger selection of plants was used. With only two plants did slight feeding take place. All four stages of *Physonota* tested nibbled leaves of *Cordia colococca* and *C. lockhartii*. (A single 5th instar larva also excised an extremely small piece from a leaf of *Phaseolus aureus*.) Further tests with these two plants indicated that *Physonota* could not complete its development on either species. Hence *Physonota* is restricted to *Cordia macrostachya* as its food plant, in Trinidad.

Biology of the Adult

A. *General habits.*

In the field during the wet season adults live on *Cordia* bushes fully exposed; and in areas where they occur may commonly be seen in numbers feeding, mating and egg laying. Their movements are slow and ponderous, and though capable of rapid short flights they rarely use their wings. Apart from the habit of dropping into the grass etc. below the bush when disturbed, the beetles have apparently no form of defence against possible predators, and it must be assumed that they are deemed unpalatable, since they are very conspicuous objects on *Cordia* bushes. Various aspects of their biology will be dealt with below and in all these points observations in the field agree with the behaviour seen in the laboratory.

B. *Feeding.*

As stated, a period of about two weeks occurs after emergence during which the adults assume the turquoise colour and hard texture of the mature beetle. During this time, however, they feed vigorously. In order to determine the amount of food consumed by an adult beetle during its life a number were taken immediately on emergence and placed singly in small cages of the same type as was used in the feeding tests.

Exact determination of the amount of food eaten per day by a single beetle was difficult owing to uncertain weight changes in the leaves provided, due to evaporation, growth, and reaction to damage by the beetle. Several methods

were considered, but eventually one was used based on the area of leaf consumed. Each morning a suitable *Cordia* twig was prepared for each cage. This twig was selected so that unwanted shoots and leaves could be easily removed so as to leave on the stem only one or two entire healthy leaves 7 to 12 cms. in length. The outline of each of these leaves was drawn on squared paper and the twig then put into position in the cage with the stem in the vial of water and the mouth of this packed with cotton wool. Thus the *Cordia* leaves showed no signs of wilting for over 24 hours. On the following morning the twig was removed and the leaves placed over their outlines on the squared paper. A second outline was drawn so that the area of leaf eaten by the beetle in 24 hours could then be easily measured by counting the number of squares difference between the two outlines. In this way daily measurements were obtained of the amount of leaf consumed by a number of individual beetles.

Certain inaccuracies in these measurements may be pointed out. Variation in the age, thickness, moisture content, etc. of individual leaves makes leaf area only an approximate measure of the weight or quantity of the food consumed. It was found, too, that in 24 hours medium-sized leaves grow a little. Although this did not seriously affect the measurements, it is a further source of inaccuracy. The figures obtained are given in Table I.

TABLE I.

Area of *Cordia* leaf eaten daily by adult *Physonota*.

A. Young adults; average figures for 3 males and 3 females.

Age of beetles in days at end of 24 hour feeding period		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Average area in 1/100th sq. inch eaten by a single beetle.	♂	24	39	64	91	84	79	65	39	81	24	36	39	52	42	37	33	28
	♀	54	47	95	109	111	83	83	58	133	48	48	86	78	71	46	89	46

Age of beetles in days at end of 24 hour feeding period . .		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Average area in 1/100th sq. inch eaten by a single beetle.	♂	48	36	44	47	61	60	32	40	46	40	43	47	20	44	42	53	53
	♀	98	71	71	57	38	112	18	71	52	60	81	65	46	-	-	-	-

Age of beetles in days at end of 24 hour feeding period . .		35	36	37	38	39	40	41	41	42	44	45	46	47	48	49	50	
Average area in 1/100th sq. inch eaten by a single beetle.	♂	105	100	39	40	98	49	-	-	-	-	-	-	-	-	-	-	-
	♀	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Average for whole period ♂ (120 beetle-days) .52 sq. inches per day.
Average for whole period ♀ (90 beetle-days) .70 sq. inches per day.

B. **Older Adults; average figures for 7 males and 4 females.**

Age of beetles in days at end of 24 hour feeding period . .		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
Average area in 1/100th sq. inch eaten by a single beetle	♂	19	22	17	21	18	23	25	25	32	23	21	41	29	39	50	20	40
	♀	96	87	112	117	95	68	73	68	86	48	53	65	58	61	54	20	41

Age of beetles in days at end of 24 hour feeding period . . .		59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Average area in 1/100th sq. inch eaten by a single beetle	♂	16	19	30	26	20	15	23	19	29	23	27	29	48	18	43	43	31
	♀	15	24	18	20	20	30	23	16	13	8	23	28	19	7	30	30	35

Age of beetles in days at end of 24 hour feeding period . . .		76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Average area in 1/100th sq. inch eaten by a single beetle	♂	30	31	25	24	44	34	41	33	35	34	35	21	37	37	22	24	18
	♀	31	21	19	22	19	33	21	26	23	24	25	29	38	56	32	7	49

Age of beetles in days at end of 24 hour feeding period . . .		93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
Average area in 1/100th sq. inch eaten by a single beetle	♂	17	38	16	25	16	41	19	45	24	25	25	16	32	14	16	17	38
	♀	82	24	72	84	43	55	27	62	55	26	25	–	–	–	–	–	–

Age of beetles in days at end of 24 hour feeding period . . .		110	111	112	113	114	115	116	117	118	119	120	121	122
Average area in 1/100th sq. inch eaten by a single beetle	♂	30	10	10	14	22	21	25	30	18	30	10	6	15
	♀	–	17	16	–	–	–	–	–	61	28	13	14	44

♂ Average for 81 days, ♂ (567 beetle-days) .26 sq. inches per day.
♀ Average for 70 days, ♀ (280 beetle-days) .40 sq. inches per day.

Certain interesting points emerged from these experiments:—

(1) *Differences between the sexes in amount of food consumed.*

From Table I it is clear that there is a difference between the areas of leaf consumed daily by male and female *Physonota* adults. Females consume 35% (young adults) to 50% (older adults) more than the males, with possibly a somewhat greater consumption by females which are actively ovipositing. This affords one method of determining the sex of the adult beetles, which cannot be distinguished with certainty on external morphological characters.

(2) *Location on leaf of areas eaten.*

It soon became apparent that the beetles did not eat parts of the leaf indiscriminately, but excisions were made usually from the basal half of the leaf, more particularly immediately adjoining the base of the mid-rib. This does not always occur and the beetles will feed readily on the leaf tips, but of 1773 of the separate areas eaten during some of these experiments 1374 (77.5%) were from the basal half of the leaf and 399 (22.5%) from the distal half. There was no significant difference in this between male and female or young and old adults. There seems no apparent reason for this preference excepting a purely mechanical one. The comparatively heavy beetle obtains a steadier hold on the leaf near the base than at the very flexible tip.

(3) *Area removed at one meal.*

From a number of observations it is possible to see the variation in the amount of leaf eaten before the beetle, if undisturbed, moves off to another part of the leaf. The variation in this is, of course, very great, but for a number of such "meals" young males gave an average of .114 sq. inches per meal, older males .075 sq. inches, young females .222 sq. inches, older females .221 sq. inches. (Average of 100 "meals" taken at random from the total feeding period for each group.)

(4) *Variation with age.*

There seems to be little variation with age in the preference for eating from the base of the leaf, but with the beginning of the condition of dormancy which the adult undergoes during the dry season (see below), feeding becomes sporadic, several days elapsing without feeding, and the amount consumed is considerably reduced. When the beetles become active with the onset of the rainy season feeding is resumed at a normal level.

C. *Mating.*

Mating does not take place until the adult beetles are fully mature and their exoskeleton has thoroughly hardened. It first occurs approximately 16 days after emergence (13 and 21 days minimum and maximum times observed.) Subsequently, when the sexes are together, mating occurs frequently at irregular intervals during the entire life. There is apparently no preliminary courtship, and the pairs remain coupled, the male dorsal to the female, for varying periods up to several days. No eggs are laid by the female until mating has occurred, but experiments have shown that a single mating is sufficient for fertilization of all eggs laid subsequently at least up to 32 days of active oviposition after the last mating, and one female has remained fertile without further mating after the period of dormancy. There also appears to be no marked stimulus to oviposition from the repeated matings of isolated pairs of beetles.

D. *Oviposition.*

This occurs on an average about 3 days (1 minimum, 6 maximum observed) after the first mating, and continues throughout life excepting, naturally, during the dry season dormant period. The eggs are laid in compact masses on any part of a *Cordia* plant or its immediate surroundings where the act of oviposition can be conveniently performed. Each mass consists of a number of eggs, 40.8 was the average number in 200 masses (maximum 78, minimum 11), and smaller masses with the individual eggs less regularly placed are laid towards the end of the life of the female. The last few eggs may be laid, not in masses, but in small unorientated groups. Each egg on being laid is copiously covered with a glutinous greyish-yellow secretion, is placed with its long axis vertical (or nearly so) to the substratum, and each one is deposited contiguous to the previous one.

The secretion hardens slowly and becomes darker, but may later be bleached in strong sunlight.

Isolated healthy pairs of *Physonota* produced on an average 1022.5 eggs each (maximum 1713, minimum 438) over a period of from 3-4 months of active oviposition. The oviposition rate of individual pairs varies little with age; once oviposition starts eggs are laid steadily until just prior to the death of the female, the post-oviposition period varying considerably, and being to a certain extent dependent on weather.

E. *Longevity.*

The length of life of the adults varies considerably with the season of the year owing to the occurrence of a long period of inactivity during the dry season. In the wet season the length of adult life of isolated individuals was about four months. Fourteen individuals of each sex under observation in the latter part of the wet season and during the dry averaged:—males 141.6 days (minimum 22, maximum 209), females 156.9 days (minimum 32, maximum 274). These results, together with all those presented in this paper were obtained at ordinary room temperature with natural seasonal and diurnal variations in temperature, humidity, etc., and hence do not have the same significance as those obtained under strictly controlled conditions.

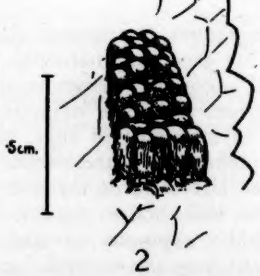
F. *Inactive Stage.*

With the onset of the dry season in January a number of the adult beetles ceased feeding, moved to a corner of their cage and remained quiescent, moving very little, and eating nothing for a period of some months. With the beginning of the wet season they resumed normal activity. This state has apparently no relation to the quality of the food, since fresh *Cordia* foliage was provided daily throughout the whole period, but is presumably related to a change in atmospheric conditions. (see page 194)

Immature Stages

A. *The Egg.*

Beneath the covering of hardened secretion each egg is cylindrical, rounded at each end, and about 2 mms. in length and .8 mm. in breadth. It is yellowish in colour and the surface of the chorion has no distinct sculpturing. An egg mass is shown in Figure 2. The eggs hatch in about 7 days.



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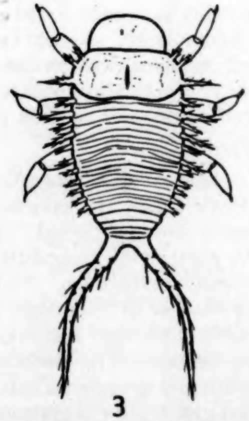
Physonota egg mass.



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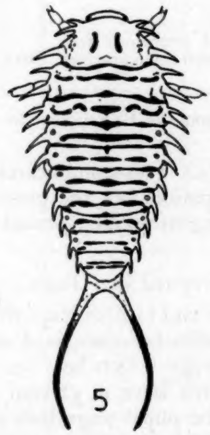
First stage larva, dorsal view.

B. *Larval Stages.*

Immediately on hatching from the egg 1st stage larvae are pale yellowish-white in colour but soon darken to black, the intersegmental membranes being somewhat paler. They are of peculiar shape (Figure 3) the two caudal processes being raised at the approach of danger. The larvae are gregarious, remaining in a compact mass on the leaf, where they feed by chewing away the surface tissue. They are found on either surface of the leaf and are active, moving en masse to fresh areas of leaf.

The general shape and location of major spinous processes of the larva are shown in the figure, but for the sake of clarity all of the smaller bristles are omitted. There is at the posterior end a pair of bristly prolongations which in life are curved over the back of the larva as in Figure 4. This stage lasts for about 3 days in the wet season in Trinidad, and gives rise to the 2nd stage larva, similar in shape to the first but the body colour is now yellow and black,

First stage larva, lateral view.



Full grown larva, dorsal view.

the caudal spines remaining black. Following this are the 3rd, 4th and 5th larval stages all similar except in size and for a lightening of the yellow coloration and a decrease in the proportion of black markings. The full-grown larva (Figure 5) is about 13 mms. in length and 7 mms. at its broadest part, behind the mesothorax, with an extra 7 mms. for the caudal appendages. Each larval stage lasts about 3 days, and at the end of a total larval life of about 17 days the full-grown larva ceases feeding.

The feeding of the larvae was investigated in some detail. On hatching the larvae feed by removing the softer parts of leaf tissue and leaving a fine "leaf skeleton"; however, as they grow they eat small holes through the leaf, and in the last stages pieces are excised from the edges of the leaf as in adult feeding. The amount of food eaten daily throughout larval life was investigated (as with the adults, from the area consumed). Fifty larvae were placed on hatching on a fresh, medium sized, *Cordia* leaf, the outline of which had been drawn on squared paper as before. After 24 hours the leaf was changed and the amount consumed estimated. The numbers of larvae surviving at the end of each 24 hours period was noted, the average number of larvae feeding in each period obtained, and the area of leaf eaten per larva per day was calculated. These experi-

ments were repeated ten times, and the average of these is given in Table II. Towards the end of the feeding period a number of the larvae cease feeding earlier

TABLE II.

Physonota Larval Feeding. Area of leaf in 1/100th square inches consumed per larva per day throughout development. Average from 10 cages each containing 50 larvae at the beginning.

Age of larvae in days at end of each day	1	2	3	4	5	6	7	8	9	10	11	12	13
Area of leaf consumed per larva in 1/100th square inches	2.2	5.3	4.7	6.1	9.3	12.0	14.1	16.9	17.9	17.7	24.3	28.9	30.8

Age of larvae in days at end of each day	14	15	16	17	18	19	20*	21	22	23	24	25	26
Area of leaf consumed per larva in 1/100th square inches	40.5	49.6	73.6	69.6	72.5	36.5	36.1	13.6	9.0	11.2	1.8	.1	-

*From the 19th day larvae were beginning to pupate.

than others. This complicates the estimates for the few days immediately preceding pupation, but the general trend is clear. The total area consumed by a larva during its feeding period is approximately 6 sq. inches. (6.043 average total feeding).

C. *Prepupa and Pupa.*

At the end of fifth stage the larva ceases feeding and after a day or so remaining motionless becomes fixed at its posterior end to the leaf surface. This is the prepupal stage which lasts for about two days, and then gives rise to the pupa, similar to the larva in general shape but with the spines replaced by blunt processes. The pupal stage lasts about 5 days before emergence of the adult.

Seasonal History

During the wet season in Trinidad (May-December) *Physonota* breeds continuously in the areas in which predators etc. permit. From the length of the life-cycle it appears that some five generations are possible in this period, but the extreme longevity of the adults entails continuous overlapping of generations. However, with the onset of the dry season in January the adult beetles gradually cease feeding and laying eggs, there being considerable individual variation in the exact date at which this occurs. As stated above this has been observed in the laboratory as well as in the field, where adults may be found in the debris on the ground near *Cordia* bushes. Correlated with this no eggs or larvae are seen in the field during the dry season, nor are any adults to be found exposed on the bushes. Four days after the rains started in 1947, on May 25th (2.13 inches), and after an extremely severe dry season, numerous adults were seen on *Cordia* feeding and mating. From their colouration it was obvious that they were old and not freshly emerged. On June 1st egg masses were observed, and the wet season cycle had started again. During the dry season this adult resting period may be broken by placing adults in a very humid atmosphere when they will soon commence feeding and oviposition. Thus this cannot be considered as true diapause (see Simmonds 1948a). This state may or may not have any adaptive significance, and it seems possible that it is dis-

advantageous for the species, which might, if it were not for this peculiarity of the adults, continue breeding throughout the dry season, when there is abundant *Cordia* for food, although it is possible that the immature stages of the beetle could not develop in continuous dry weather.

In an endeavour to correlate this assumption of inactivity with one or more definite factors an analysis was made of some of the meteorological data obtained at St. Augustine (Imperial College of Tropical Agriculture) at the time that these observations were made. In Table III daily mean maximum and minimum

TABLE III.

Meteorological data, St. Augustine 1946–47, together with numbers of *Physonota* adults entering and emerging from the dormant state in the laboratory.

Weekly Period	Daily mean Maximum °F	Daily mean Minimum °F	Mean Minimum % R.H.	Rainfall in inches	No. of *Physonota* actively feeding
Nov. 2– 8	87.0	71.9	63.4	1.69	17
9–15	87.7	70.7	59.6	.37	17
16–22	85.0	72.3	70.4	3.91	17
23–29	86.0	69.6	62.4	.78	17
30– 6	86.1	69.7	62.4	.22	17
Dec. 7–13	85.6	69.1	65.6	1.99	15
14–20	85.7	70.1	61.6	.92	12
21–27	85.4	69.4	64.7	7.04	8
28– 3	84.1	70.0	63.3	.99	7
Jan. 4–10	83.7	70.3	65.3	.58	5
11–17	84.1	69.7	59.6	.44	3
18–24	84.1	67.0	58.7	.45	1
25–31	84.7	66.9	57.6	.20	1
Feb. 1– 7	85.1	68.7	60.4	.27	—
8–14	84.9	66.4	55.6	.02	—
15–21	87.3	68.0	53.3	—	—
22–28	87.1	67.0	53.1	—	—
Mar. 1– 7	86.7	67.9	51.4	—	—
8–14	87.0	69.9	49.9	.03	—
15–21	87.4	69.4	48.3	.06	1
22–28	87.0	69.3	51.7	.02	3
29– 4	87.3	73.4	53.9	.02	4
April 5–11	88.0	72.0	51.3	—	8
12–18	88.3	69.6	49.6	.05	8
19–25	89.8	70.7	49.1	—	9
26– 2	89.7	69.1	47.6	—	9
May 3– 9	89.3	71.7	50.4	.28	12
10–16	89.6	73.6	51.3	.02	12
17–23	90.7	71.6	48.0	—	13
24–30	86.0	74.3	65.4	4.41	17

temperatures, and minimum relative humidities, have been averaged for weekly periods, total rainfall shown for these periods, and also the number of experimental beetles feeding in the laboratory (only those are considered which survived the dry season and resumed normal activity following it). Consider first the resumption of activity after the dry season. In the field this occurred immediately after the first rain, and was obviously dependant on this. However, in the laboratory no such precipitation occurred, and it was found that resumption of

activity was spread over a long period commencing nearly two months earlier than the first heavy rain, hence some other factor is involved here. Secondly consider the dates of commencement of inactivity. Field observations on this were not made, but collections indicated that, as in the laboratory, it occurred over a long period. In the laboratory some individuals ceased feeding at the beginning of December and one continued feeding until the end of January before becoming inactive. It is seen from Table III that cessation of activity anticipates the beginning of the major declines in rainfall, mean relative humidity, and mean minimum temperature. It is possible that the cessation of activity may be correlated with mean maximum temperature, but this seems unlikely. It may be due to a combination of factors or to individual minimum threshold values of any of these factors. It is clear, however, that though the resumption of activity in the field is caused by the first rain the assumption of inactivity is not caused by this factor. Further investigation of this would provide a very interesting field for experiment and an opportunity to correlate results with field data.

Parasites and Predators

It would appear from their behaviour that the adults of *Physonota* are comparatively immune to predators. The beetles remain fully exposed on the leaves and twigs of *Cordia* and are very conspicuous with their metallic blue colouring. The immature stages are, however, heavily parasitised, and predators may under certain circumstances take heavy toll of the larvae (see below).

A. *Egg Parasites.*

The species commonly reared from *Physonota* egg masses collected at Caroni are *Horismenus* sp. and *Syntomosphyrum* sp. both of which appear to be primary parasites. Emergents from a typical collection of egg masses made on September 5th, 1946, are shown in Table IV. If these emergents are considered further and eggs which have not been susceptible to parasite attack are excluded, it is possible to obtain a better idea of the true degree of parasitism (see Simmonds 1948b). Under the heading of "valid emergents" in Table IV figures are given which were obtained by discarding those emergents from egg masses which had already partially emerged when collected, and also those which, from the date of emergence of the host larvae, had probably been too young for parasite attack in the field. A few egg masses gave both *Horismenus* and *Syntomosphyrum*, hence the apparent discrepancy in the totals of egg masses.

The degree of parasitism fluctuates considerably with both time and locality, but it is on the whole very high, and the figures in Table IV are representative, excepting for the beginning of the wet season when, after the adults have started to become active again, parasitism is low, and takes some time to increase to its usual level.

Of neither species of egg parasite has the life history been worked out in detail. A single parasite apparently emerges from each egg, and usually if an egg mass is attacked all, or nearly all, of the eggs are parasitised. Thus the numbers of egg masses parasitised, irrespective of the numbers of individuals involved, also gives a good estimate of the degree of parasitism. Egg masses producing both species of parasite are uncommon. In the Trinidad wet season the developmental time of both species is about 15 days.

B. *Larval Parasites.*

A Tachinid, *Eucelatoriopsis* sp. (possibly a new species) has consistently been reared from field collected larvae, and a small number of *Brachymeria* sp. (Chalcididae) have emerged from pupae. Parasitism is not high; small collections

TABLE IV.

Physonota Egg Parasitism. Collection of egg masses made at Caroni, Trinidad. September 5, 1946.

	Numbers of Emergents					Total Egg Masses Producing:				
	Physonota	*Horismenus*	*Syntomosphyrum*	Total Parasites	Total Emergents	*Physonota* only	*Horismenus*	*Syntomosphyrum*	Total parasitised	Total masses
Total Emergents	104	533	64	597	701	4	39	7	45	49
%	14.8	(89.3	10.7)	85.2		8.2	(84.8	15.2)	91.8	
Valid Emergents	31	382	64	446	477	1	27	7	32	33
%	6.5	(85.6	14.4)	93.5		3.0	(79.4	20.6)	97.0	

have been made giving a parasitism of 50% by the Tachinid, but the average figure is around 20%.

The life histories of these parasites have not been investigated. From the extensive breeding of *Physonota* in the laboratory it would appear that parasitism does not occur through the ingestion by the host larva of Tachinid eggs laid on the foliage, but that young host larvae are attacked and parasitized. The parasite larva develops within the host as the latter is growing, and when the *Physonota* larva forms a prepupa the parasite larva finishes feeding, emerges from the skin of the prepupa and forms a puparium, from which the adult fly emerges some 10 days later.

The mode of attack by *Brachymeria* has not been observed, but other species of the genus deposit eggs within the host pupa. The adults emerge, one from each pupa, from a circular hole bitten through the dorsal part of the thorax.

C. *Predators.*

The action of predators in checking increase of *Physonota* has been investigated, particularly with regard to the difficulty of establishing colonies of the beetle in parts of Trinidad other than the Caroni and neighbouring areas, as mentioned above. In this connection a number of experiments were carried out. Egg masses, larvae in different stages, pupae and adults were put out on *Cordia* bushes both in the field and in large pots in the laboratory garden. In the latter case it was found that if ants were prevented from gaining access to the larvae by means of a band of tanglefoot round the trunk, or by means of a water barrier round the pots, later stages of larvae disappeared, and that the disappearance occurred during the daytime. Observations showed that wasps (*Polistes canadensis* L.) were primarily responsible for this, though some larvae were removed by spiders. In the field, however, birds may play their part, although in all the experiments it was obvious that the depredations of ants is the main factor in reducing the numbers of larvae, and that where certain ant species are present nearly all larvae are removed as they hatch. Birds may also destroy some egg masses, as a number of these have been found damaged in the field.

Samples of ants crawling over *Cordia* taken on the same day from both Caroni and the area in St. Augustine where colonization of *Physonota* was

attempted without success were kindly identified by Dr. M. R. Smith in Washington. At Caroni there were present *Camponotus zoc* Forel, *C. sexguttatus* (F.), *Pseudomyrma elegans* (F.), *P. gracilis* var *agilis* Em., *Pseudomyrma* sp., *Paratrechina longicornis* (Latr.) and *Ectatomma ruidum* Roger. In the St. Augustine collection there were *Solenopsis geminata* (F.), *Solenopsis* sp., *Camponotus zoc* Forel, *Brachymyrmex* sp., *Pseudomyrma gracilis* var *agilis* Em. *P. flavidula Smith*, and *Ectatomma ruidum* Roger. It is noteworthy that the very predaceous species *Solenopsis geminata* is present at St. Augustine but absent from Caroni, and this suggests that this species is mainly responsible for the non-establishment of *Physonota* in St. Augustine. This would possibly affect the establishment of *Physonota* in Mauritius since *S. geminata* is a pest there.

It is evident in Trinidad that owing to the action of both predators and parasites on the immature stages the numbers of *Physonota* are so reduced that this species is only able to survive in certain restricted localities where conditions, presumably connected with drainage and soil type, are unsuitable for certain species of ants. This action entirely offsets the very high powers of reproduction of the adults, their longevity and immunity from attack, all of which would help them to colonize fresh areas.

It is difficult, if not impossible, to give definite quantitative values of the reduction in numbers caused by parasites and predators since these values vary considerably in both space and time, but is obvious that such action is considerable.

General

This investigation of the biology of *Physonota* was undertaken primarily to ascertain the potentialities of the species as a controlling agent for the serious weed pest in Mauritius, *Cordia macrostachya*, and a brief summary may be made of this aspect of the biology. In the first place the actual damage to the reproductive capacity of *Cordia* by partial defoliation must be established. Preliminary experiments on this have already been recorded (Callan 1948), and there has been previous work on experimental defoliation of grasses (Lyubimenko, Eidel'man, Schevchenko etc. 1933). Further experiments are also being carried out here with *Cordia*, and it seems clear that partial defoliation causes a definite decrease in number of seeds set, and that, as one might expect, complete defoliation repeated at very frequent intervals entails the death of the plant. The figures given here for the amount of food consumed by adult and developing *Physonota* enable some idea to be formed of the numbers of beetles necessary to produce severe defoliation in a given area of *Cordia*. Secondly, the food habits of all stages of the beetle have been thoroughly investigated, since its specificity for *Cordia macrostachya* must be assured before attempting its introduction into another area with the possibility of its attacking plants of economic value. It has been seen that *Physonota*, under Trinidadian conditions, is very specific for *Cordia macrostachya*. Study of the biology of the species shows that its reproductive potential is very high, and that it is kept in check in Trinidad by parasites and predators. Hence, if the latter are absent in Mauritius, the chance of its successful establishment is great. However, it may be found that native Maurician species will attack *Physonota*, restricting its increase in the same manner as in Trinidad. This would, of course, diminish or completely destroy the value of the species as a control agent against *Cordia*. Further points that may be noted in favour of the species are the apparent immunity of the adults to predators, their longevity, and their capacity for remaining inactive over long periods of dry weather. It has been pointed out that this inactivity is probably of no advantage to the species when the food plant is plentiful, but would be a distinct advantage if it coincided with periods of scarcity of *Cordia* leaves. This in-

activity has also been utilized in the shipment of the species to Mauritius. Since air service from the West Indies to Mauritius is slow and somewhat uncertain it is difficult for a number of species to survive the journey. However, adult *Physonota* shipped in the inactive state during the dry season survived very well.

It may be concluded that the details of the biology of *Physonota* indicate that, if successfully established in Mauritius, it should cause considerable defoliation of *Cordia* and may be of some importance as a control agent.

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Benzene Hexachloride (BHC) as a Rapid Control Agent for White Grubs (*Phyllophaga* spp.)[1]

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The effectiveness of benzene hexachloride (BHC) when applied to pasture sod as a control for June beetles was demonstrated (1) during 1947 at Marmora. Tests were continued during 1948 to determine the control value of the same contact insecticide against second-year, second- and third-instar larvae at the summer-feeding level in sod land.

A block of field plots was laid out in a pasture which was so severely infested by second-year grubs that it was expected to show most extensive destruction of sod before the end of the summer. It was considered as a most suitable area to determine the efficiency of BHC, in terms of sod protection and white grub mortality.

The experimental block consisted of 6 rows, 300 feet long and 4 feet wide, alternating with check rows 3 feet wide and 300 feet long. Liquid spray was applied with a power sprayer at the rate of 60 gallons per acre. The site was a well-drained slope, with a relatively low water table, a sandy surface, and subsoil of considerable depth. Organic matter of the surface soil was relatively low and was largely confined to the upper 4 inches of the surface soil.

A miscible form of BHC containing 25 per cent gamma isomer was applied at rates of 0.25, 0.50, 1.00, 2.00, 4.00, and 8.00 pounds of gamma isomer per acre on June 14. No additional water was applied and for some time afterward the area was lightly pastured by cattle.

The first series of counts for comparative populations of white grubs was undertaken on July 27, the second on July 29, and a third on September 1, representing periods of 43, 45, and 78 days from the date of application of BHC. Precipitation from June 14 to July 29 was 5.08 inches, with an additional 1.71 inches to the end of August.

Six samples, one foot square, were dug at intervals of about 50 feet along the central section of treated and check strips at each sampling. Only in the first series were dead white grubs recovered in any numbers, and therefore a comparison could not be made on the basis of living and dead grubs. In the following table, populations are given for treated and check rows at the various strengths of insecticide.

Discussion

On the basis of comparative populations in check and treated rows, concentrations above 2 pounds of gamma isomer per acre gave relatively high control. At and below the 2-pound rate, control values on the basis of population only were not striking.

On the basis of sod protection, however, control values were much more obvious. The sod in all treated strips was in better condition and showed more green grass than the check strips, although those treated with 0.25 to 1 pound of gamma isomer had considerable cut-off sod. The sod of the 2-pound treated strip was injured by white grubs only in spots, with no sod detached below the surface, regardless of the insignificant number of white grubs recovered. At 4 and 8 pounds of gamma isomer, all sod was green and uninjured by white grubs, but the 8-pound treated strip had better grass growth than did the 4-pound strip,

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White Grub Populations

BHC gamma isomer (pounds)	1st Count		2nd Count		3rd Count		Totals	
	Treat-ment	Check	Treat-ment	Check	Treat-ment	Check	Treat-ment	Check
0.25	45	53	29	36	24	45	98	134
0.50	40	41	19	43	19	30	78	114
1.00	71	55	35	38	12	19	118	112
2.00	33	35	17	35	23	22	73	92
4.00	3	52	2	37	7	11	12	100
8.00	0	68	0	49	2	25	2	142

indicating at least that this rate did not deter grass growth. The marginal line between the latter treatment and the adjoining check strip and outside untreated margin was very sharply defined between the green and dead sod.

The BHC treatment, applied on June 14, was made somewhat in advance of the heavy annual feeding of second-year white grubs; but at the first sampling, in late July, sod was very conspicuously injured in untreated pastures and meadows. At that time, pasture grass had not suffered because of insufficient moisture.

The occurrence of dead grubs in the first series of samplings and not in the next two indicated that the principal mortality occurred during early or mid-July, either when soil temperature conditions were optimum or when white grubs were especially vulnerable to the action of the contact insecticide, a condition strongly suggested by various other contact insecticide tests on second-year, third-instar white grubs.

Conclusions

Eight pounds of gamma isomer of BHC per acre gave perfect sod protection under most severe infestation conditions, with the margins of the treated strips very sharply defined. The 4-pound rate also gave excellent sod protection under similar outbreak conditions, regardless of a larger differential of grubs in the treated row. At a 2-pound rate, good sod protection was secured, regardless of 10 per cent injury, most apparent where the sod in adjacent check strips was completely cut off. At 1 pound and less, between 0.25 and 1.0 pound, considerable cutting by white grubs was apparent, although in each case the condition of the treated sod was better than that of the accompanying check strip.

Earlier application of the insecticide to sod would probably have the effect of increasing the mortality of the second-year grubs, due partially to greater general activity during the early part of the summer and also to an apparently definite, progressive resistance of the grubs during the latter part of the summer.

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The Influence of Spray Programs on the Fauna of Apple Orchards in Nova Scotia. III. Mites and their Predators[1]

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Introduction

The commercial production of apples has led growers to greater reliance on chemical control measures for pests than have most fields of agricultural production. Since the turn of the century orchardists have plunged deeper and deeper into artificial measures to produce fruit free from blemishes without greatly alleviating the over-all pest problem and, in some cases, actually producing conditions conducive to still greater problems.

The failure of entomologists to consider the latent effects of sprays on the fauna of the orchard, even though the immediate effects against a particular pest may have appeared desirable, was criticized by Pickett *et al.* (9). They expressed the belief that a very large factor in the increasing damage from insect pests is the disturbance created, by chemical control measures, in the relative balance between pests and their natural enemies. Experimental evidence that this was true with the oystershell scale, *Lepidosaphes ulmi* (L.), was presented in a previous paper by the author (3) in which it was demonstrated that the natural enemies of the scale were destroyed by the sulphur sprays applied for the control of apple scab, *Venturia inequalis* Wint.

Complementary to other portions of the long-term studies on the effects of sprays on the fauna of apple orchards were studies initiated in 1944 on the mite fauna and on the insect predators of mites. The European red mite, *Metatetranychus ulmi* (Koch) [=*Paratetranychus pilosus* (C. & F.)], the clover mite, *Bryobia praetiosa* Koch, and the predators of both of these species, because of their economic importance, have received much more attention than the saprophytic and incidental bark-inhabiting species. The latter have, however, been kept under observation in the search for possible future pests and because they may be important as a measure of the general balance of species in the orchard economy.

A large number of species is involved and our knowledge of their biology and interactions is scanty. A good deal of exploratory work was therefore required. A large fund of information of a general nature on the life histories, habits, and food requirements of a number of important species has been gathered, but detailed ecological research on many of the species becomes increasingly important as the story unfolds. At the present stage a general knowledge of all the species existing in the orchards and of the role played by each in an environment modified by various spray practices is of practical economic value and of basic importance in the organization of more intensified studies on the important species. The studies have been confined to mites and their predators, but since in nature these species are only a part of the biological complex, the relationships of the predators to other species demand investigation.

Methods

Because a multiplicity of ecological factors determines the population densities of the various species in an orchard at a given moment, a spray material interjected into the environment may have a differential effect upon each species. It may be a catastrophic mortality factor for some species and not for others

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because of the differences in their resistance to the toxic effects of the spray. On the other hand, species susceptible to the spray may be able to escape adverse influences through characteristics in their life-histories and habits. Predators in general are sporadic in occurrence for biological reasons which have nothing to do with the spray used, and consequently great care must be exercised in interpreting the effects of sprays.

Experimental plots are basic to research on the fauna of orchards where the spray is an ecological factor that can be added to the environment at will. However, orchards cannot be found which will, individually, include within their environment all the ecological factors for even one organism. Therefore, the variety of environmental conditions in commercially sprayed orchards, considered collectively, has made observation in them a necessary supplement to the studies in the experimental plots. Conclusions about the effect of each spray material on each species must be drawn conservatively, even after wide observation, since the same result may be due to more than one cause.

Laboratory studies may serve a restricted but useful function in the analysis of the less complex aspects of a problem under more or less controlled conditions. Unidentified species may be reared to maturity for specific determination, the life-histories of the species investigated, the prey consumed per unit of time measured, and other studies of like nature pursued without the complications encountered under natural conditions. The reactions of a predator in the laboratory are, however, no real measure of the role played by the species in the orchard, where a much more dynamic complex of environmental factors determines its density and effectiveness. In the final anlaysis, observations on numerous occasions, together with a summation of the knowledge gathered from all sources, have governed the conclusions with respect to the direct and indirect effects of sprays in the orchard.

A series of applications of the individual fungicides or insecticides in fairly large blocks of orchard is the most practical means of determining which species are affected by the spray and at which stage they are most likely to be affected. Each spray material has been used alone as much as possible, but it was usually necessary, for practical reasons, to combine two or more materials in the spray program. This has been particularly true of the insecticides, since in Nova Scotia a fungicide is needed during certain seasons of the year to preserve the foliage from apple scab.

A technique still largely in the developmental stage involves the single application of individual chemicals to one or two trees known to have certain predators. A measure of their detrimental effect on the predators may be made by counting the predacious species on the leaves before and several times after spraying, or by collecting those which drop on to a unit area after the application.

A method for the accurate estimation of the populations of very active predators in the orchard does not seem to be available. Some workers have used observational methods based upon the numbers seen in a stated time, usually one hour, or other methods of comparison in which the numbers of predators cannot be directly related to the prey population on a similar unit. This weakness was not overcome in the course of the work in Nova Scotia during the past few years. The method utilized during the first year or two was simply that of periodically examining each block of orchard sufficiently long to ascertain which species of predators were abundant or scarce. Later a folding tray, one square yard in area and covered with cotton, was found to be a valuable aid in expanding and speeding up the observations. The tray was held beneath the lower limbs of a

tree while they were vigorously tapped by another worker to dislodge predators on to the tray. This technique was particularly useful for very active insects before they acquired wings and before the apples became too large to remain on the trees when the limbs were tapped. On some occasions this method of sampling could be used throughout the season where trees could be found with a small crop.

For the gross sampling of arthropods on a tree, a fast-acting dust was applied to individual trees in each plot. The dust, a mixture of 6 per cent DDT, 10 per cent derris, and 30 per cent pyrethrum, was applied with a small power duster on a calm morning about the time the dew was disappearing. Five cones of heavy paper, the open ends of which totalled approximately 16 square feet, were suspended beneath the tree, and at the bottom end of each of the larger cones a small detachable cone was fastened. This method, like those described above, did not give a statistical measure of the numbers of predators, but it was a valuable aid in determining their relative abundance.

The populations of mites on the leaves could be readily measured by microscopic examinations in the orchard. In this phase of the work the same trees were used throughout the studies, and each season they were periodically sampled. The same trees as those from which the leaf samples were taken were used for the winter records on mite eggs. Leaf samples give a satisfactory representation of the density of the population of the European red mite, of *Iphidulus tiliae* (Oud.), and, to a lesser degree, of *Mediolata novae-scotiae* Nesbitt. The clover mite is not so well represented by leaf samples because of its habit of wandering on to the twigs, where many of the mites pass through the quiescent stages and many of the eggs are laid. A measure of the population of the clover mite based on leaf samples is, therefore, somewhat low but still sufficiently accurate to give a practical measure of the trends in the orchard.

For the winter eggs of the phytophagous mites it has so far been impossible to obtain a sampling unit which will permit the direct comparison of the summer and winter populations of these species. The winter eggs of the red mite and of the clover mite are deposited all over the bark, in groups varying from large numbers on the lower sides of the bases of the main limbs to small numbers in the axils of the small twigs. It is thus impossible to measure, during the winter, the numbers of mite eggs on any unit that is as representative of the tree population as are the leaves. A reasonably comparative measure of the differences between plots may be made, however, by limiting the observations to the axils of twigs up to five or six years in age. A count of the full and empty eggs per axil would be impractical because of the large numbers that would have to be counted to eliminate the effect of the great natural variation. With the number of axils that it would be practical to examine in this way the average amount of predation could be determined, but it would be a poor measure of the average number of eggs laid on each axil. To obtain these data and the average number of eggs surviving after the fall predation, the following system of estimation was used: The axils of 500 to 1000 twigs were examined, and the numbers of normal and of empty eggs were estimated on each axil according to somewhat arbitrary but convenient categories.

Because of the way in which the eggs are scattered along the twigs, it is often difficult to decide on an estimate of the number of eggs. To set some limits, and to obtain as much uniformity as possible, all the eggs around the base of the axil and for one-half of an inch out on the twig were taken as the standard of measurement.

The Relative Importance of the Predacious Arthropoda in the Natural Control of Mites

The economic importance of the European red mite in Nova Scotia has, in these studies, focused more attention upon it and the predacious species important in its control than upon the other mites. The clover mite is at present of no economic importance in commercial orchards, since it is destroyed by the sulphur sprays generally used for the control of apple scab. In those orchards in which iron carbamate (ferric dimethyl dithiocarbamate) or copper fungicides (bordeaux mixture and copper oxychloride sulphate) have been used in the bloom applications in place of sulphur, the clover mite has, in general, been controlled largely through the activities of its natural enemies. The damage to the foliage from attacks of the clover mite is very similar to that caused by the red mite but is usually confined to the leaves near the centres of the trees. The clover mite will need close observation as each new material is introduced into the spray program, since it has the potentialities of a pest if it should survive treatments with materials which destroy its natural enemies.

The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, has never been a pest of apple trees in Nova Scotia, having been found only in small numbers in a few instances in the fall of the year. What is presumably the same species is often very numerous in gardens and sometimes does considerable damage. The observations on this species have been too cursory to permit a conclusion as to its potentialities as a pest of apples in Nova Scotia.

Usually the predacious species prey on both of the important phytophagous species, with certain exceptions to be discussed later. Under the great variety of environmental conditions in orchards a predator that is usually of minor consequence may have an economically significant effect if it is present in sufficient numbers. It frequently happens, too, that a spray material destroys one or more of the effective predators, and then because of the increased density of the mite population less efficient predators may become of considerable importance. With very rare exceptions it has been found that at least several species of predators were preying upon the mites and that no one species could be specified as the controlling agent. A previous account of the predators of the European red mite in Nova Scotia based on observations from 1932 to 1935 was published by the late F. C. Gilliatt (2) in 1935. The reader is referred to that paper for details of the biology and habits of a number of these predators. In the discussion of the predators of mites in the following part of this paper it will be necessary to point out certain discrepancies in Gilliatt's interpretations. He worked entirely alone on the project before ideas with respect to the indirect effects of sprays had crystallized. The writer wishes to express his appreciation of the value of Gilliatt's work as the background to these studies on mites and their predators. A criticism of certain of his interpretations is not intended in any way as a reflection on the quality of his work.

Acari

(a) *Iphidulus tiliae* (Oud.) [=*Typhlodromus tiliae* (Oud.)]

Dr. H. H. J. Nesbitt, Professor of Zoology, Carleton College, Ottawa, while engaged in a study of mites on apple trees in the Annapolis Valley, observed several closely related species of typhlodromids. These had formerly all been confused under the name of *Seiulus pomi* Parrott, but the common one is the species described by Garman (1) as *I. fallacis*. Nesbitt has compared specimens with Oudeman's types and has come to the conclusion that *I. fallacis* is a synonym of *I. tiliae* and that it is by far the most common typhlodromid on apple trees in

Nova Scotia. The results of his studies on the mites of apple trees in Nova Scotia will be published shortly, and in his paper the taxonomy and synonomy of the species related to *I. tiliae* will be discussed in detail. Gilliatt (2) discussed a predacious typhlodromid important in the control of the red mite under the name of *Seiulus pomi* Parrott. It is highly probable that the species which he observed was *I. tiliae*, since Nesbitt's work has shown that this is the common one, and *I. pomi* (Parrott) as described by Garman (1) has not been found in Nova Scotia.

I. tiliae feeds readily on eriophyids and has been observed to seize the active forms of *Tydeus robustus* Banks. It probably feeds on the eggs of most of the mite species and is known to be an important natural enemy of the eggs of the red mite. Nesbitt (6) found in the laboratory that *I. tiliae* would feed on the eggs of the clover mite only under pressure of starvation. This relationship appears to hold under orchard conditions as well, as is indicated in the results (Table XIII) from the Hiltz-South Yarmouth orchard. On the copper-sprayed plot of this orchard small number of *I. tiliae* have been consistently associated with a low density of the European red mite in spite of the presence of moderate numbers of the eggs of the clover mite. Had clover mite eggs been a favoured food of *I. tiliae*, an increase in the numbers of the latter species would have been expected and a greater control of the clover mite attained.

Further observation and field studies have shown clearly that Gilliatt (2) was in error about the adverse effect of bordeaux mixture on *I. tiliae*. Although his tests in the laboratory had apparently shown that bordeaux destroyed these mites, the method of testing was evidently not representative of field conditions.

Furthermore, in his discussion of the plots at Berwick in 1931 Gilliatt showed that there were more red mites in the "bordeaux" plot than in the lime-sulphur plots. In this experiment what he considered a bordeaux plot actually had wettable sulphur sprays in the bloom period to avoid russeting of the fruit. It is now known that the use of sulphur in the bloom period would have destroyed *I. tiliae*. In the experiment, the lime-sulphur sprays in the other plots were presumably sufficiently toxic to the red mite to check its increase. The bordeaux being innocuous to the red mite and the wettable sulphurs having destroyed *I. tiliae*, the increase in the red mite on the so-called bordeaux plot is not surprising.

Gilliatt's appraisal of *I. tiliae* as the most important predator of the European red mite in Nova Scotia appears to be correct. It has been frequently observed that this mite may suddenly increase in numbers in the late summer in orchards which have been sprayed with materials detrimental to it, such as sulphur or iron carbamate. This increase often takes place too abruptly to be accounted for by simple biological increase; it seems much more indicative of a movement of the species from the ground or low-growing plants.

The writer believes that much of the predation on winter eggs of the red mite which Gilliatt attributed to *I. tiliae* may have been due to the predacious thrips *Haplothrips faurei* Hood, as has certainly been the case since the present studies were initiated. Gilliatt had rated this thrips as of minor consequence but stated that he had observed it in late August and early September. Actually, in sulphur-sprayed orchards, it is very active late in September and through October.

The adverse effect of flotation sulphur on *I. tiliae* is illustrated in Tables XIII and XV. Very strong additional evidence is deduced from the extreme scarcity of *I. tiliae* in a large number of sulphur-sprayed commercial orchards despite the fact that its favoured prey, the red mite, was moderately numerous in most

of these orchards. Iron carbamate acts in much the same way as sulphur on populations of *I. tiliae*, as was shown in the Sutton, Palmer, and Wolfe orchards (Tables XVI, XVIII, and XIX), in which iron carbamate was used in the spray program. In a test at the Experimental Station, Kentville, N.S., summer oil at the rate of 1 gallon to 100 gallons of spray was very detrimental to *I. tiliae* (Table 1). There has been no opportunity to supplement this test with observations on larger blocks of orchard where an oil application was required to control the red mite. The scarcity of *I. tiliae* was in most instances due to spray materials applied for other purposes, and the small numbers of this predator were very probably an important factor contributing to the need for supplementary measures to control the red mite. Lead arsenate (Table IV) and synthetic cryolite (Tables I and IV) in small, single-application tests had no detrimental effect on *I. tiliae*, and the results from the copper-sprayed plot of the Hiltz-South Yarmouth orchard lend confirmatory evidence. In the Hiltz-South Yarmouth orchard both lead arsenate and synthetic cryolite were used in the post-blossom applications without any apparently adverse effect on *I. tiliae*. The only information on the effects of nicotine on *I. tiliae* is that contained in the results from the small-scale tests presented in Tables I, II, and IV. Fixed nicotine appears to have little if any repressive effect, but nicotine sulphate seems somewhat detrimental to the *I. tiliae* population. In all instances in which DDT has been used on an extensive scale in larger blocks of orchard it has been incorporated into sprays or has followed sprays such as sulphur or iron carbamate which are detrimental to *I. tiliae*, and it has, therefore, been necessary to rely on the results of small tests. A single application of DDT was very destructive to *I. tiliae* in these tests, as shown in Tables II, III, and IV. Phygon (Dichloronaphthoquinone), which has been under test as a fungicide, appears to have delayed detrimental effect upon *I. tiliae* (Table V) after a single application. Officers of the Dominion Laboratory of Plant Pathology at Kentville have treated an experimental plot with five applications of this material each year for the past three years, and during that time very few *I. tiliae* have been found during the spraying season.

Table I

I. TILIAE *on Starking leaves from trees in the Variety block at the Dominion Experimental Station, Kentville, N.S., sprayed on August 27, 1947.*

Materials per 100 gal.	*I. tiliae* per 100 leaves	
	Sept. 2	*Sept. 8*
Flotation sulphur, 15 lb.	53	60
Wettable sulphur, 8 lb.	114	60
Summer oil, 1 gal.	4	12
Synthetic cryolite, 4 lb.	111	226
Fixed nicotine,* 4 lb.	235	276
Water-sprayed check	257	352
Unsprayed check	116	284

* Black Leaf 155.

(b) *Mediolata novae-scotiae* Nesbitt

This mite, described by Nesbitt (5) as a new species in 1946, is one of the more important predators of the clover mite, but it does not appear to be capable of keeping the clover mite in check unless aided by other predacious species. *M. novae-scotiae* is a sluggish species, lemon-yellow in colour but characteristically appearing orange to red when it has been feeding on clover mite eggs. Apparently *M. novae-scotiae* does not feed readily, if at all, on red mite eggs in the orchard; but it will seize eriophyids and the mite *Czenspinskia lordi* Nesbitt, a feeder on fungal mycelia found only on trees that have not been sprayed for several years. Even though common on completely neglected

TABLE II.

I. TILIAE *on Stark leaves from trees in the G. West orchard, sprayed on August 15, 1948.*

Materials per 100 gal.	*I. tiliae* per 50 leaves		
	Just before spraying	Aug. 19	Sept. 10
Check (1st tree)	—	58	88
Check (2nd tree)	—	69	101
Check (3rd tree)	—	63	—
DDT, 2 lb. (50%) (1st tree)	73	4	1
DDT, 2 lb. (50%) (2nd tree)	—	2	—
Nicotine sulphate, 1 pt. (1st tree)	94	11	43
Nicotine sulphate, 1 pt. (2nd tree)	—	4	30
Fixed nicotine, 4 lb. (1st tree)	71	39	51
Fixed nicotine, 4 lb. (2nd tree)	—	69	59

TABLE III

I. TILIAE *on the leaves of DDT-sprayed trees in the Drew Orchard and the Hiltz-South Yarmouth Orchard, 1944.*

	I. tiliae per 50 leaves	
	Just before spraying	A few days after spraying
McIntosh—Drew Orchard	33	0
Stark—Hiltz-South Yarmouth Orchard	16	0
Gravenstein—Hiltz-South Yarmouth Orchard	50	0
Stark Check—Hiltz-South Yarmouth Orchard	14	6
Gravenstein Check—Hiltz-South Yarmouth Orchard	6	7

McIntosh sprayed in Drew orchard on July 12.
Stark in Hiltz-South Yarmouth orchard sprayed on July 24.
Gravenstein in Hiltz South-Yarmouth orchard sprayed on August 1.

TABLE IV

I. TILIAE *on Ben Davis and Gravenstein leaves from trees in the South Sawler Orchard, sprayed on July 23, 1948.*

Materials per 100 gal.	Average *I. tiliae* per 50 leaves			
	Aug. 2	Aug. 9	Aug. 23	Sept. 13
Check	32	—	67	56
Nicotine sulphate, 1 pt.	4	15	20	36
DDT, 2 lb. (50%)	0	0	1	13
Lead arsenate, 4 lb.	15	21	27	36
Synthetic cryolite, 4 lb.	30	75	65	66

TABLE V.

I. TILIAE *on Gravenstein leaves from trees in the South Sawler Orchard, sprayed on August 2, 1948.*

Materials per 100 gal.	*I. tiliae* per 50 leaves				
	Before spraying	Aug. 4	Aug. 10	Aug. 23	Sept. 13
Check	37	—	34	—	56
Phygon, 1 lb. (1st tree)	—	42	12	8	2
Phygon, 1 lb. (2nd tree)	—	32	15	4	4

trees, *M. novae-scotiae* has not been seen in large numbers on these. In the few orchards in which *M. novae-scotiae* has been present in fairly large numbers, the only fungicides used were copper fungicides (Tables XIII and XV). There are as yet some unexplained differences in the natural control of the clover mite on completely neglected and on copper-sprayed trees, the clover mite always being more numerous on the copper-treated trees than on the neglected ones. With this increase in the population of the clover mite there is also an increase in the predacious mite *M. novae-scotiae,* which feeds on clover mite eggs. Even with increased numbers of *M. novae-scotiae* the clover mite maintains a higher level of population on the copper-sprayed trees than on neglected trees. The data in Tables XIII and XV indicate that flotation sulphur destroys this predacious species, but more evidence is needed, since the sulphur appears to destroy the only two species found in sprayed orchards upon which it is known to prey. Wide observation and the results in Tables XIV, XVI, XVII, XVIII, and XIX demonstrate that iron carbamate is very detrimental to this species. Lead arsenate and synthetic cryolite are innocuous to *M. novae-scotiae,* since both materials were used in the codling moth control sprays in the Hiltz-South Yarmouth plots with no repressive effect on the population of *M. novae-scotiae* (Table XIII). Very little information as to the effects of the other spray materials on this mite is yet available.

(c) *Anystis agilis* Banks

This is a large, very active, crimson-coloured, predacious mite which preys upon a large number of species of mites and small insects. Since chance encounter seems to govern its search for food, it seems likely that its value in the control of any one species depends upon the numerical relationships of all the species upon which it feeds; that is to say, it feeds most often upon the species it encounters most frequently. Nothing is known as yet about its preferences in prey, and these preferences, if any, will modify the effects due to chance encounter. Table VI shows that iron carbamate and copper fungicides have little if any effect upon these mites but that the addition of lead arsenate to the iron carbamate is very detrimental. Iron carbamate with and without lead arsenate was tested in the North Sawler Orchard (see later description) and it is possible that the greater populations of red mite and clover mite (Table XIV) where the lead arsenate was used were due in part to the destruction of *A. agilis.* Nesbitt (6) has shown that there are two generations of this mite each year, the eggs being laid on the ground and the larvae moving back to the apple trees. This habit probably enabled them partially to escape the effect of sodium dinitro-o-cresylate in the Boyle orchard (Table VI) and has enabled them to become more numerous in the late summer where other detrimental materials have been

TABLE VI

A. AGILIS *per Ben Davis tree in the Aldershot orchards after dusting with a fast-acting dust (5 trays per tree or 16 sq. ft.)*

Date	Iron carbamate	Iron carbamate and arsenic	Sulphur	Copper	Iron carbamate and DNC*
			1945		
Aug. 28	74	1	0	268	0
Sept. 6	30	39	—	—	—
			1946		
May 28	17	7	0	0	0
June 25	17	0	0	11	0
July 4	56	0	0	1	3
Aug. 9	15	3	0	5	13
Aug. 31	48	2	0	4	0
			1947		
May 27	0	0	0	0	0
June 21	0	0	0	0	0
July 17	3	0	0	0	0
Aug. 2	48	0	0	0	0
Aug. 28	34	0	0	4	0
			1948		
June 17	0	0	0	0	0
July 13	7	0	0	2	1
Aug. 11	43	2	0	48	13

*Sodium dinitro-o-cresylate as a dormant treatment in 1945, 1946, and 1948.

TABLE VII

A. AGILIS *per tray (1 sq. yd.) in the Aldershot orchards in 1948 after tapping the lower limbs of Ben Davis trees to dislodge the predators.*

Date	Iron carbamate	Iron carbamate and arsenic	Sulphur	Copper	Iron carbamate and DNC
May 20	0	0	0	—	0
June 1	6	0	0	0	0
June 22	14	—	11	1	—
July 20	23	0	1	31	85
Aug. 4	14	2	2	35	6
Sept. 15	92	0	6	27	—

used in the spray program. There is evidence from Table VI that flotation sulphur destroys or repels these mites, since the presence of large numbers of red mites should have provided ample food (Table XV). The extreme scarcity of *A. agilis* in commercial orchards is probably due to their repression by the arsenicals and possibly also by the sulphur sprays. There is some evidence, not as yet confirmed, that synthetic cryolite and nicotine sulphate are not severely detrimental to *A. agilis.*

(d) *Other Acari*

In orchards which have not been sprayed or subjected to cultural treatment for several years there are a number of predacious species which are rarely found in orchards treated for commercial production. These species include such forms as *Eupalus parvus* Ewing, *Eupalus biscutum* Nesbitt, *Cunaxa* sp., *Cyta latirostris* Herm., *Atomus* sp., mites of the Phytoseiinae group, and probably others. There are also numerous bark-inhabiting species of no known importance. The predacious mite *Hemisarcoptes malus* (Shimer), important in the control of the oystershell scale, has been discussed in a previous paper (3).

Araneae

Several small species of spiders have been observed to seize the active forms of the European red mite, but where there is a dense population of the mites the spiders have been of very minor importance. Under the more natural conditions of uncared-for orchards in which the red mite population is normally at a very low level, spiders may possibly be more important in the maintenance of a low density of the mites. Observations have been made on the numbers of spiders in the experimental plots, but it has not been possible as yet to demonstrate that any of the commonly used spray materials are toxic to spiders.

Thysanoptera

(a) *Haplothrips faurei* Hood

Under the conditions of the current commercial spray practices, whereby the density of the European red mite is usually much above the natural level, the thrips *Haplothrips faurei* Hood is one of the most important factors in the natural control of the red mite. Sulphur appears to have the property of repelling or destroying *H. faurei*, but, although the thrips may be scarce in the early summer, it is usually abundant in the late fall in those orchards with a high population of red mites. The possible confusion by Gilliatt (2) of its work with that of *I. tiliae* in the late fall has already been discussed. The large numbers of thrips found in association with large numbers of red mite eggs in the fall appear to be due to the tendencies of the thrips to disperse and to the attraction of large

numbers of red mite eggs. This infiltration of the thrips is not, however, limited to the fall, as the thrips may become plentiful at any time during the growing season if the density of the red mite is sufficiently great and no deterrent material, such as sulphur, is in use. This thrips may also be present in smaller numbers under favourable spray conditions even when there are only a few mites. Though the occurrence of *I. tiliae* under favourable conditions appears to be almost inevitable, the numbers of *H. faurei* under the same circumstances are much more sporadic.

MacPhee (4) found that there were three generations of this thrips each year although there appeared to be great overlapping of generations. The winter is spent in the adult stage but the adults have never been found on apple trees in winter.

This thrips also feeds readily on clover mite eggs and is probably a general feeder on mite and insect eggs. In the laboratory MacPhee found that it would feed readily on eggs of the eye-spotted bud moth, *Spilonota ocellana* (D. & S.).

TABLE VIII

H. FAUREI *per tray* (*1 sq. yd.*) *after tapping the lower limbs of Starking trees in the Tobin orchard and of King trees in the Sutton orchard.*

Tobin: bordeaux — iron carbamate with nicotine sulphate.
Sutton: bordeaux — iron carbamate with lead arsenate.

Date of sampling	Sutton orchard		Tobin orchard	
1947				
June 20	–	Red mite and clover mite fairly heavy, becoming light.	21	Red mite rather heavy, becoming light.
July 4	–		41	
July 16	41		–	
July 23	155		–	
July 29	144		158	
Aug. 13	50		111	
Sept. 9	–		65	
Sept. 14	212		119	
Sept. 29	–		98	
Oct. 9	–		40	
1948				
May 28	–	Red mite and clover mite light.	66	Red mite light, increasing somewhat later in season.
June 18	2		23	
July 27	–		0	
Sept. 14	–		33	

TABLE IX

HILTZ-SOUTH YARMOUTH ORCHARD—H. FAUREI *per tray* (*1 sq. yd.*) *after tapping the lower limbs of Baldwin trees in the Hiltz-South Yarmouth orchard in 1947.*

Date	Copper	Sulphur	
July 10	34	6	Red mites plentiful on the sulphur plot but not on the copper plot.
July 31	9	2	
Sept. 11	64	168	
Sept. 17	15	245	

It may be that the thrips has no special preference for the eggs of the red mite and that the apparent preference may simply be associated with the mathematical odds in favour of its finding red mite eggs more often. If so, the degree to which the thrips feeds upon the eggs of the predacious mite *I. tiliae* would not be of great economic significance, since the eggs of the latter are always much less numerous than those of the European red mite.

In the Tobin orchard (Table VIII), where nicotine sulphate was used as the insecticide in a bordeaux-iron carbamate spray program, the numerical status of *H. faurei* was evidence that this thrips survived or escaped the effects of nicotine sulphate. A further discussion of the effects of the thrips on the mite population is given in a later section in which the results in the Tobin orchard are examined in more detail.

In 1947 in the Sutton orchard, where lead arsenate was the insecticide in a bordeaux-iron carbamate fungicide program, large numbers of these thrips were associated with a fairly high density of red mite (Table VIII) and decreased as the population of the red mite declined.

Copper fungicides have little if any adverse influence on *H. faurei*, the relatively small numbers on the copper-sprayed plots (Tables IX and X) being

Table X

Aldershot Orchards — H. faurei *per Ben Davis tree in the Aldershot orchards after dusting with with a fast-acting dust.* (*5 trays per tree or 16 sq. ft.*)

Date	Iron carbamate	Iron carbamate and arsenic	Flotation sulphur	Copper	Iron carbamate and DNC
1945					
Aug. 28	4	0	0	6	0
Sept. 6	3	0	—	—	—
1946					
May 28	0	0	2	4	3
June 25	2	3	1	5	4
July 4	0	0	1	4	7
Aug. 9	13	16	14	39	2
Aug. 31	7	10	0	44	0
1947					
May 27	0	0	1	4	3
June 21	0	4	2	0	1
July 17	2	3	0	28	11
Aug. 2	1	2	10	82	5
Aug. 28	3	15	13	16	48
1948					
June 17	3	3	0	2	13
July 13	0	5	7	42	18
Aug. 11	5	8	65	160	9

The red mite was abundant in 1947 and 1948 in the sulphur plot and in the iron carbamate plot in which sodium dinitro-o-cresylate (DNC) was used as a dormant spray.

associated with the small numbers of mite eggs. On the sulphur plots the records in the same tables show large numbers of thrips but only after the last sulphur spray had been on the trees for some weeks. It is evident from this experiment and from general experience in commercial orchards treated with sulphur sprays that sulphur is detrimental to *H. faurei.* The only evidence that this thrips is destroyed by DDT was its extreme scarcity in a number of orchards where DDT was incorporated into a bordeaux-iron carbamate program.

(b) *Other predacious thrips*

Several other thrips feed upon red mite eggs and probably also on eggs of the clover mite, the feeding in the latter case having been observed only in the laboratory. These species are *Leptothrips mali* (Fitch), *Zygothrips minutus* Uzel, and *Scolothrips sexmaculatus* (Pergande).

L. mali has been observed in moderately large numbers on several occasions in commercial orchards where bordeaux and iron carbamate fungicides were applied. In these instances a number of other predators were at work, but as no extensive observations were made, their relative value was not determined. In 1948 these thrips were rather numerous in two commercial blocks which received post-blossom applications of nicotine sulphate and fixed nicotine (Black Leaf 155).

Z. minutus has been observed in the act of attacking eggs of the red mite, but this species has been found mainly in those experimental orchards which have received only copper fungicides. Very small numbers have also been seen in a few instances in blocks sprayed with bordeaux and iron carbamate. At present this species is of little economic importance because of its small numbers. It apparently hibernates under flakes of bark on the trunks, where it was found in samples from the Hiltz-South Yarmouth copper-sprayed plot. Examination before and after an unusually cold spell (probably -25°F.) in 1948 indicated that extreme cold destroyed this thrips, since no survivors could be found after the second search although numerous dead specimens were located.

S. sexmaculatus appears to be fairly widely distributed, but has been noted only in very small numbers and for that reason is of little economic significance. It has not been seen by the writer to feed on eggs of the red mite in the orchard, but several workers have referred to it as a predator of the red mite.

(TO BE CONTINUED)

Obituary

J. F. C. Fryer A. D. Imms F. Silvestri

We regret to announce the death, during the past few months of three workers each of whom contributed greatly in his special sphere to the advancement of entomological science.

Sir John Fryer, who was born on August 13, 1886, received his education at Cambridge University. After participating in several scientific expeditions to the Indian Ocean, he became the first Entomologist to the Board of Agriculture of the United Kingdom and later the Director of the National Laboratory of Plant Pathology at Harpenden. He was largely responsible for the organization of the advisory and quarantine services of the Ministry of Agriculture. He served on many important scientific bodies and in 1938-39 was President of the Entomological Society of London. He was knighted in 1946 and elected a Fellow of the Royal Society of London in 1948. His extensive knowledge in the field of scientific agriculture was recognized by his appointment to the important post of Secretary of the Agricultural Research Council. The heavy pressure of his official duties and his rather indifferent health in later years considerably restricted Fryer's work in the field of pure science; but owing to his official position and his keen appreciation of the value of research, his influence on the development of entomology in Great Britain was great and beneficial.

Dr. A. D. Imms, best known to entomologists by his excellent "Text Book of Entomology" and the successive editions of his "Recent Advances in Entomology", was born on August 20, 1880. He was educated in the Universities of Birmingham and Cambridge. After graduating from Cambridge he spent several years as Professor of Biology in the University of Allahabad, India. From 1911 to 1913 he was Forest Zoologist to the Government of India, after which he returned to England to become Reader in Entomology in the University of Manchester (1913-18). In 1918 he was appointed Chief Entomologist of the Rothamsted Experiment Station. In 1931 he accepted a position as Reader in Entomology in the University of Cambridge, where he remained until his retirement in 1945. In 1929 he was elected a Fellow of the Royal Society of London and was later made a Corresponding Member of the French Academy of Agriculture and a Foreign Member of the American Academy of Arts and Sciences. He was President of the Royal Entomological Society of London in 1936-37.

Imms was a man of fine character, a hard, careful and accurate worker with an unusual endowment of strong common sense. He died in a little over four years after his retirement after a painful illness, whose serious nature he carefully concealed in order to avoid distressing his family.

Professor Filippo Silvestri, was born in Bevagna, in the province of Perugia, Italy, on June 22, 1873 and died in the same place on June 10, 1949 just before completing his 76th year. According to my information, he continued to act as Director of the Entomological Laboratory in Portici, Naples, until the age of 75. At the International Congress in Stockholm, in August of last year, he presented a long and valuable paper on problems of biological control.

Silvestri was a man of strong and genial personality and immense energy: perhaps, indeed, the most remarkable entomologist of his generation. Following in the steps of Antonio Berlese, but with extremely meagre resources, he succeeded, almost single-handed, in making Portici recognized as one of the great world centres of entomological work. By exchanges obtained with the Bulletin published by his laboratory and to which he was the principal contributor, he

built up an excellent local library. His own contributions covered an immense field in both pure and applied entomology. He worked specifically on Chilopods, Thysanura, Protura, Isoptera, Embioptera, Psocoptera, and Strepsiptera and incidentally on many other groups. The discovery of the Protura and the Zoraptera was due to him. He was one of the earliest students of polyembryony and the first to reveal (in Litomastix) the existence of the remarkable asexual larvae sometimes formed during this process. He was not an experimentalist in the modern sense; but his monographs of injurious insects and their natural enemies contain a wealth of morphological and anatomical information and are abundantly and excellently illustrated. Silvestri had also a deep interest in biological control and carried out extensive explanations for parasites in many parts of the world, one of the most important being the search for parasites of the Mediterranean Fruit Fly (the account of which was translated at Silvestri's request by the present writer). Here again the results obtained singlehanded and with the most meagre equipment, were remarkable.

Only a man of exceptional mental capacity could have produced Silvestri's scientific output. But he had also, like Berlese, an extraordinary capacity for continuous hard work. The working day, in the period I spent in the Portici Laboratory, extended from 7.00 a.m. to 7.00 p.m., with two hours interval for lunch. No member of the staff was allowed to deviate from this tempo. My sojourn in Portici dissipated once and for all, the common American illusion that Italy is poor because the Italians are lazy.

The scientific achievements of F. Silvestri were widely recognized. He was a member of the Pontifical Academy of Science, of the ancient Academy of the Lincei and a foreign and honorary member of some 30 foreign academies and societies. He was also, throughout his career, in spite of his distinctions, a kind, hospitable and friendly gentleman.

W. R. Thompson.

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